DNV GL RP for RBI of Topside Static Equipment

John Eapen

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**SCOPE**

- The pressure system boundaries for applicability of the methods are the christmas tree wing valve through to the export pipeline topsides ESD valve. This involves the following types of components:
  - piping systems comprising straight pipe, bends, elbows, tees, fittings, reducers
  - pressure vessels and atmospheric tanks
  - pig launchers and receivers
  - heat exchangers
  - unfired reboilers
  - valves
  - pump casings
  - compressor casings.

- Excluded from the scope of the recommended practice are:
  - structural items including supports, skirts and saddles
  - seals, gaskets, flanged connections
  - failure of internal components and fittings
  - instrumentation.
RBI Working Process

1. Grouping, classification and risk analysis planning
2. Risk acceptance criteria (Appendix B)
3. Hazard identification
4. PoF (Appendix A), CoF (Appendix C)
5. Risk analysis
6. Risk evaluation (Section 4)
7. Inspection and monitoring program (Appendix F)
Steps in an RBI process

- Data Collection
- Screening
- Detailed Assessment Data Collection
- Detailed assessment – Pof Calculation
- Detailed Assessment – Cof Calculation
- Risk Estimation
- Inspection Plan generation
Data Collection - Documents Required to Perform An RBI

- Line list
- Equipment list
- System descriptions manual
- Equipment data and vessel sheets
- Piping data sheets
- Layout drawings, process flow diagrams (PFDs), utilities flow diagrams (UFDs), piping and instrumentation diagrams (P&IDs), process and safety diagrams (PSDs)
- Design, fabrication and installation (DFI) resume
- Inspection/failure/replacement history knowledge
- Corrosion protection philosophy
- Material design specification and selection report
- Coating specifications
- Insulation specifications
- Quantitative risk analysis (QRA)
- Design accidental load analysis
- ESD logic diagrams
- Mass balance sheets
- Production data (past and future)
- Key operation and maintenance personnel.
Risk Based Inspection (RBI)

- Risk = Likelihood of Failure × Consequence of Failure
- $= \text{PoF} \times \text{CoF}$
## RISK MATRIX

<table>
<thead>
<tr>
<th>PoF Ranking</th>
<th>PoF Description</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>(1) In a small population, one or more failures can be expected annually.</td>
<td>YELLOW</td>
<td>RED</td>
<td>RED</td>
<td>RED</td>
<td>RED</td>
</tr>
<tr>
<td></td>
<td>(2) Failure has occurred several times a year in the location.</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>(1) In a large population, one or more failures can be expected annually.</td>
<td>YELLOW</td>
<td>YELLOW</td>
<td>RED</td>
<td>RED</td>
<td>RED</td>
</tr>
<tr>
<td></td>
<td>(2) Failure has occurred several times a year in operating company.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>(1) Several failures may occur during the life of the installation for a system comprising a small number of components.</td>
<td>GREEN</td>
<td>YELLOW</td>
<td>YELLOW</td>
<td>RED</td>
<td>RED</td>
</tr>
<tr>
<td></td>
<td>(2) Failure has occurred in the operating company.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>(1) Several failures may occur during the life of the installation for a system comprising a large number of components.</td>
<td>GREEN</td>
<td>GREEN</td>
<td>YELLOW</td>
<td>YELLOW</td>
<td>RED</td>
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<td></td>
<td>(2) Failure has occurred in industry.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(1) Several failures may occur during the life of the installation for a system comprising a large number of components.</td>
<td>GREEN</td>
<td>GREEN</td>
<td>GREEN</td>
<td>YELLOW</td>
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</tr>
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</tbody>
</table>

### CoF Types
- **Safety**: No Injury, Minor Injury Absence < 2 days, Major Injury Absence > 2 days, Single Fatality, Multiple Fatalities
- **Environment**: No pollution, Minor local effect, Can be cleaned up easily, Significant local effect, Will take more than 1 man week to remove, Pollution has significant effect upon the surrounding ecosystem (e.g., population of birds or fish), Pollution that can cause massive and irreparable damage to ecosystem.
- **Business**: No downtime or asset damage, €10,000 damage or downtime < one shift, €100,000 damage or downtime < 4 shifts, €1,000,000 damage or downtime < one month, < €10,000,000 damage or downtime one year

### CoF Ranking
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<td></td>
</tr>
</tbody>
</table>
### RISK MATRIX FOR SCREENING

<table>
<thead>
<tr>
<th>Probability of Failure</th>
<th>Risk Categories and Screening Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td><strong>MEDIUM RISK</strong>&lt;br&gt;Inspection can be used to reduce the risk, but is unlikely to be cost-effective; the cheapest solution is often to carry out corrective maintenance upon failure.</td>
</tr>
<tr>
<td>4 &gt;10^-5</td>
<td><strong>HIGH RISK</strong>&lt;br&gt;Detailed analysis of both consequence and probability of failure.</td>
</tr>
<tr>
<td>3</td>
<td><strong>LOW RISK</strong>&lt;br&gt;Minimum surveillance, with corrective maintenance, if any. Check that assumptions used in the damage assessment remain valid, e.g. due to changes in operating conditions.</td>
</tr>
<tr>
<td>2</td>
<td><strong>MEDIUM RISK</strong>&lt;br&gt;Consequence is high so actions (such as preventative maintenance) should be considered to ensure continued low probability as small changes in conditions can increase PoF and give high risk.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consequence of Failure</th>
<th>Acceptable consequence of failure</th>
<th>Unacceptable consequence of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B C D E</td>
<td></td>
</tr>
</tbody>
</table>
Objectives of Screening

- Information exchange workshop with operator
- Identify and screen out obvious low risk equipment
- Move High risk equipment for detailed assessment
Calculation of the PoF

Knowledge of Materials Tells us What Failure Mode to Expect
Pof Estimation (Degradation)

- The rate at which degradation takes place depends on the following parameters:
  - 1) Material of construction
  - 2) Contents of the part (product services) (for internal degradation)
  - 3) Environment surrounding the part (for external degradation)
  - 4) Protective measures
  - 5) Operating conditions.
Pof Estimation (CS Degradation)

- **External Corrosion**
  - Uninsulated CS
  - Insulated CS

- **Internal Corrosion**
  - Erosion
  - Water
  - Microbiologically Induced Corrosion
  - C02 Corrosion
  - H2S Cracking
Pof Estimation (SS, Cu Ni Degradation)

- **SS External Corrosion**
  - Uninsulated
  - Insulated - Local Corrosion
  - Insulated – External Stress Corrosion Cracking

- **SS Internal Corrosion**
  - Water

- **Cu Ni Internal**
  - Water
Leak leading to a consequence

1. Discharge
2. Dispersion
3. Ignition (Flammables)
4. Consequence
# Cof Assessment

## Ignited leak

<table>
<thead>
<tr>
<th>Safety consequence</th>
<th>Economic consequence</th>
<th>Environmental consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consider loss of life due to:</td>
<td>Consider the costs of:</td>
<td>Consider the effects of:</td>
</tr>
<tr>
<td>– burns to personnel</td>
<td>– repair of damage to equipment and structure</td>
<td>– toxic gas release</td>
</tr>
<tr>
<td>– direct blast effects to personnel</td>
<td>– replacement of equipment and structural items</td>
<td>– smoke.</td>
</tr>
<tr>
<td>– indirect blast effects to personnel (missiles, falling objects)</td>
<td>– deferred production</td>
<td></td>
</tr>
<tr>
<td>– injuries sustained during escape and evacuation.</td>
<td>– damage to reputation.</td>
<td></td>
</tr>
</tbody>
</table>

## Unignited leak

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<tr>
<td>Consider loss of life due to:</td>
<td>Consider the costs of:</td>
<td>Consider the effects of:</td>
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<td>– asphyxiating gas release</td>
<td>– repairs.</td>
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<tr>
<td>– impingement of high pressure fluids on personnel.</td>
<td></td>
<td></td>
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</tbody>
</table>
# Example of time to inspect

<table>
<thead>
<tr>
<th>PoF Ranking</th>
<th>PoF Description</th>
<th>Time to Inspect (years)</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>Corrective Maintenance</td>
<td>4</td>
</tr>
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<th>Business</th>
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<td></td>
<td>No Injury</td>
<td>Minor Injury Absence &lt; 2 days</td>
<td>Major Injury Absence &gt; 2 days</td>
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<td>No Fatality</td>
<td>Significant local effect, pollution has significant effect upon the surrounding ecosystems (e.g., population of birds or fish).</td>
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<td>No pollution</td>
<td>Pollution that can cause massive and irreparable damage to ecosystem.</td>
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<td>Multiplicity of Fatality</td>
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<td>Minor local effect, pollution can be cleaned up easily.</td>
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**Time to Inspect Limit**

- The time at which \((PoF = PoF_{\text{Limit}})\) is given by:

\[
\text{Time to PoF}_{\text{Limit}} = a \frac{t_0 - t_{\text{release}}}{d_{\text{mean}}}
\]

- Where:
  - \(t_0\) = Current wall thickness (mm).
  - This can be determined by inspection.
  - \(t_{\text{release}}\) = Wall thickness at which a release is expected (mm).
  - This can be derived from first principles, or from appropriate codes or formula such as ANSI/ASME B31.3 ANSI/ASME B31.G, BS 5500, ASME VIII, and DNVGL-RP-F101, using relevant operational loads.
  - \(d_{\text{mean}}\) = Mean damage rate (mm/year). This is determined using measured values, expert judgement, or the guidance in App.A
  - \(a\) = Confidence factor.
### Inspection Techniques Table F1

- Damage Mechanism
- Damage Description
- Inspection Method
- Inspection Effectiveness
Deliverables of an RBI Assessment to Inspection Program

- Prioritisation of high risk components
- Determination of inspection intervals
- Expected damage mechanisms
- Selection of best inspection method
- Data requirements for continuous improvement

WHAT to inspect
WHEN to inspect
WHERE to inspect
HOW to inspect
WHAT to report
Reasons for selection risk based approach to Inspection Planning

- A systematic overview of the installation is achieved together with an explicit, systematic and documented breakdown of the installation’s risks clearly showing the risk drivers and recommending appropriate actions.
- Inspection efforts are focused on items where the safety, economic or environmental risks are identified as being high; whilst similarly the efforts applied to low-risk systems are reduced.
- Probabilistic methods can be used in calculating the extent of degradation and hence allow variations and uncertainties in process parameters, corrosivity, and thus degradation rates and damage extent, to be accounted for.
- Consequences of failure are considered, so that attention can be focused where it will have significant effect. If there are significant uncertainties in the outcomes, these can be modelled by investigating the probabilities of the various outcomes using an event tree approach.
- Contributing in a pro-active and focused manner to ensuring that the overall installation risk does not exceed the risk acceptance limit set by the authorities and/or operator.
- Identifying the optimal inspection or monitoring methods according to the identified degradation mechanisms and the agreed inspection strategy
Benefits of RBI

- Identification of High risk and Low risk items in a plant
- Reduce of focus on low risk items
- Optimal focus on High risk items in terms of inspection strategies
- Availability of database of all piping and static equipment in the plant and the corrosion circuits they belong to
- Awareness in plant on exact degradation mechanisms that each item is exposed to
- Availability of an inspection plan based on degradation an item is exposed to and time to inspect based on when item becomes critical
- More non intrusive inspection techniques reducing shutdown times
- Effective use of shutdown times to take corrective actions on defects observed during non intrusive inspection
- Updates can be made if there are any changes in operating conditions, material of construction, personnel distribution
Thank You

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